Professional Paper 14-72

HumRRO PP-14-72

HumRRO

AD 748082

Perspectives on Simulation and Miniaturization

Michael R. McCluskey

HUMAN RESOURCES RESEARCH ORGANIZATION
300 North Washington Street • Alexandria, Virginia 22314

Presentation at
U.S. Continental Army Command
Training Workshop
Fort Gordon, Georgia October 1971

June 1972

Prepared for

Office of the Chief of Research and Development
Department of the Army
Washington, D.C. 20310

19

The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation. HumRRO's mission in work performed under contract with the Department of the Army is to conduct research in the fields of training, motivation and leadership.

Published
June 1972
by
HUMAN RESOURCES RESEARCH ORGANIZATION
300 North Washington Street
Alexandria, Virginia 22314

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Human Resources Research Organization (HumRRO) 300 North Washington Street Alexandria, Virginia 22314	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

PERSPECTIVES ON SIMULATION AND MINIATURIZATION

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Professional Paper

5. AUTHOR(S) *(First name, middle initial, last name)*

Michael R. McCluskey

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1972	15	48

8a. CONTRACT OR GRANT NO. DAHC 19-70-C-0012 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) PP-14-72 9b. OTHER REPORT NO.(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Paper presented at CONARC Training Workshop, Fort Gordon, Ga. Oct 71	Office, Chief of Research and Development Department of the Army Washington, D.C. 20310

13. ABSTRACT

Training applications of simulation and miniaturization are examined, as are areas where research is needed to develop cost-effective simulation methodologies for training. In order for simulation and miniaturization techniques to reach maximum levels of effectiveness, systems analysis is needed to define physical and psychological dimensions, relationships, and aspects. Among the aspects of the system to be considered for simulation are equipment components, personnel, organization, system procedures and processes, input data, output data, and environment.

DD FORM 1 NOV 65 1473

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Military Training						
Miniaturization						
Miniaturization Techniques						
Simulated Environment						
Simulated Training						
Simulation						
Simulation Techniques						
Systems Analysis						
Transfer of Training						

Prefatory Note

This paper [illegible] Command Training [illegible] in October 1971. Research for the paper was performed under Work Unit MARKSMAN, Combat Marksmanship, by the Human Resources Research Organization, Division No. 4, at Fort Benning, Georgia, where Mr. McCluskey is a Research Scientist.

PERSPECTIVES ON SIMULATION AND MINIATURIZATION

Michael R. McCluskey

Introduction

The purpose of this presentation is to suggest a conceptual framework for making decisions regarding the use of simulation. It will cover such aspects as the applications of simulation, the factors involved in selecting a simulation methodology, the aspects of the system to be simulated, and the conditions necessary for transfer to the real world. Finally, we will examine some training applications of simulation and miniaturization, and indicate areas where research is needed.

Before proceeding, I would like to define simulation as we will be using it: Simulation is a physical, procedural, or symbolic representation of certain aspects of a functioning system (Fitzpatrick, 1962)[1]—a working model or representation of a real-world system.

Applications of Simulation

There appear to be four basic areas of endeavor where simulation techniques have been applied (Crawford, 1967; Gagne, 1954; Smode, *et al.*, 1962): training, performance measurement, system evaluation, and research.

These techniques have been frequently used in the area of training, where the objective of the simulation is to provide the trainee with a learning environment that will facilitate the acquisition of the knowledge and skill required to function effectively in the system being represented. The most crucial aspect of this application is creating conditions that will provide transfer of training to the real-world system.

Performance measurement is the second major area where simulation has been found useful. The purposes of simulation in this case are to determine the limits of proficiency, criterion levels of performance, research requirements, and training needs. The measurement conditions created must also provide reliable and valid estimates of performance that may be generalized to tasks and functions in the real system.

Simulation techniques have also been useful for system evaluation. The feasibility and capability of the system to meet its objectives are relatively simple to evaluate in a simulated environment. The effectiveness and contribution of certain subsystems and system modifications may also be determined in addition to the overall effectiveness of the system.

Simulation techniques have also found considerable use for research purposes. The simulation in research provides a controlled environment in which most parameters affecting the system may be examined, quantified, and controlled. Since these activities will be continually introducing change in the system, a constant check must be maintained on the extent of transfer of the findings.

Although these four areas do possess certain unique characteristics and impose specific requirements on the creation of the simulation, they certainly are not independent. The purposes of simulation for any given system would be likely to include most, if not all, of these areas.

[1]The definition of simulation given by Fitzpatrick has been slightly modified to meet the needs of this paper.

Reasons for Simulation

Among the reasons for using simulation techniques in our activities instead of other methodologies are expense and time; safety; ethical or political constraints; past, future, or hypothetical events; and control over real-world events. In many cases, the very nature of the system we are dealing with dictates that we use some form of simulation[1] (Redgrave, 1962; Rogers, 1959). The cost and time involved in operating large military or industrial systems are simply prohibitive. Due to the amount of equipment and the number of personnel needed for real-world operations, we must turn to simulation techniques to make time and expense factors manageable.

Other systems may be too dangerous to exercise in the real world. We cannot use the real-world system to learn to hit aircraft with air defense weapons. Through the use of simulation for training, however, many of the skills involved can be raised to a high level of proficiency.

Ethical and political positions restrict the use of other systems in the real world. A soldier cannot be placed in a live combat situation simply to study the effects of stress on performance. The combat conditions that will produce this psychological state must be approached through simulation.

It is also necessary to use simulation techniques if we are to examine the effects of past events or conditions on a new system, or if we are going to predict the effects of future events. Hypothetical events or conditions must also be simulated in order to determine the reactions to unfamiliar situations and completely define the capability of the system.

Other systems such as those involving the accuracy and performance of air-to-air missiles are extremely difficult to control in the real world for experimental purposes. In order to precisely control and measure the variables involved in such systems, we may again turn to simulation.

Advantages of Simulation

There are several other advantages in the use of simulation that may provide sufficient justification in themselves for selecting this particular methodology (Bogdanoff, *et al.*, 1960; Rogers, 1959; Smode, *et al.*, 1963). Simulation provides an excellent environment for training personnel to function effectively in a system. Many of the variables in the learning environment may thus be controlled and measured by the instructor so that he may make adjustments in the programs to meet the individual needs of the trainees. In addition, the simulated situation will provide the trainee with immediate knowledge of results without the detrimental consequences of incorrect actions in the real world.

Another advantage of simulation is control over the dimension of time. In the case of rare events or situations that develop slowly, such as large-scale air defense engagements or tactical exercises, simulation lets us speed up the process to make the time frame for observation more suitable for our purposes. Likewise, for events that occur too rapidly for accurate observation and analysis, such as complex psychomotor performance, the sequence of events can be slowed to a more practical rate.

Precise control over situational and experimental variables is another important advantage associated with simulation techniques. This allows us to evaluate experimentally the variables related to the simulation technique itself and also various aspects of the system being simulated. We may also introduce other variables that might otherwise be difficult to control or administer.

[1] The use of simulation techniques to improve Army training was explored by Robert A. Baker, Jr., and William L. Warnick, HumRRO Division No. 2, Fort Knox, Kentucky.

Simulation also makes possible a relatively unlimited number of replications under the same or different conditions in order to develop predictive relationships concerning the performance of the system.

Simulation techniques provide the capability for economically testing and evaluating system performance during exploratory and developmental stages. In vehicle design, several control functions and configurations may be evaluated in terms of operator capability. In this manner, proposed changes or additions to the system may be evaluated before final development and production. These techniques also allow identification and definition of training problems at an early point so that the necessary modifications may be incorporated during the development phase. During development or operation, we may also extract certain subsystems, aspects, or components of the system for test and evaluation.

Simulation also assists in simplifying the complex environments within which some systems must function. We may extract the most relevant variables from the environment for incorporation in the simulation, or we may systematically vary different combinations of environmental variables.

System Aspects

After the decision to use simulation techniques either through necessity or to obtain certain advantages has been made, we must determine what should be simulated. In order to decide which aspects—equipment components, personnel, organization, system procedures and processes, input data, output data, environment—we will simulate, we must have a thorough understanding of the total system and how the various aspects relate to it and to each other. Fitzpatrick (1962) has proposed a taxonomy of system aspects that seems appropriate. The equipment components refer to the hardware associated with the system or its subsystems and subcomponents. The personnel are all the people included in the system and their respective job responsibilities and functions. The organization includes both formal and social relationships and interactions between groups or individuals. The procedures and processes of the system refer to the rules by which the system operates. Input data are those that provide the necessary and sufficient basis for system operation. The products that the system has been designed to produce are regarded as output data, and the quality of these data will form the basis for determining the adequacy of the system. The environment is intended to include all other variables and situations, which are not a part of the system but form the operational setting. Before proceeding with the construction of a simulated system, it is necessary to have complete and accurate information concerning the aspect of the system being simulated in order to place it in the proper perspective.

Simulation Definition

Since we have selected the methodology of simulation and determined the general area of interest within the system, a fuller definition of simulation is required. Once we have operationalized this definition or specified the procedures to be used in making our observations and measurements, the simulation will be complete. One meaningful definition for simulation is a physical, procedural, or symbolic representation of certain aspects of a functioning system (Fitzpatrick, 1962). Simulation then is a working model or representation of the system, and it is assumed that the observations made can be transferred to the real system in the form of predictions about its performance.

Our definition of simulation contains several items that require further specification before we may construct the simulation. Physical, procedural, or symbolic refer to the general type or form that the simulation will take. Representation is probably the most critical word since it has direct implications for the degree of transfer to the real world.

It refers to the fidelity of the simulation or the extent to which the average state of the system is represented. "Aspects" refer to the part of the system we are simulating and "functioning" indicates that we will conduct our activities within an operational and active system.

When we use simulation techniques, it is our intention that the observations and findings will transfer and apply to the real-world system. Since this is our ultimate purpose and objective, defining the conditions of transfer becomes the most important phase in the use of simulation techniques. The degree of transfer appears to be directly related to fidelity or the extent to which we can accurately represent the system in our simulation.

The fidelity of simulation is composed of both physical and psychological dimensions. Physical fidelity is concerned with the extent to which the simulation represents the environment and operational equipment of the real system. Psychological fidelity refers to the degree of similarity we can create in the psychological demands of tasks in the simulated and real systems. Several studies have indicated that psychological fidelity is more important for adequate transfer than physical fidelity (Cox, *et al.*, 1965; Grimsley, 1969; Isley, 1968; Muckler, *et al.*, 1959; Prophet and Boyd, 1970). Although it is probably true that high fidelity simulation is a necessary condition for transfer, it is a matter of which dimensions and attributes should be selected and how accurately they should be represented to obtain cost-effective transfer.

In the development of any simulation, we must determine the levels of physical and psychological fidelity that will be cost-effective in terms of the amount of transfer. For the most part, these relationships are unknown, but it appears that more emphasis should be given to psychological fidelity. A considerable amount of research is needed in this area in order to completely define the conditions of optimum transfer from simulated environments. In the absence of information concerning these relationships, there appears to be a tendency to request high physical fidelity as a precaution. In the majority of the systems, this is a fairly expensive safeguard of unknown value. The expenditure of funds to achieve high fidelity simulation probably far exceeds the amount that would have been needed for systems analysis and research to determine the levels of physical and psychological fidelity required for equal or better transfer.

Types of Simulation

Our first action toward implementing simulation techniques should be a determination of the general type of simulation to be employed. Harman (1961) has suggested several varieties of simulation—replication simulation, miniaturization, laboratory simulation, computer simulation, analytical simulation—that tend to vary along a dimension of physical abstraction from the real world.[1] The spectrum extends from a high fidelity replication of the system in the form of an operational model to mathematical modeling. Our task is to determine at which level of abstraction we can best represent all aspects of a system for cost-effective transfer.

Psychological Dimensions of Simulation

It appears that the conditions of transfer from our simulated environment will be primarily determined by an identification of the psychological dimensions involved in the tasks and the degree of fidelity with which they should be represented. Crawford (1956)

[1] Miniaturization has been added to the types of simulation given by Harman since it is not a complete replication due to the reduced-scale, but it is more than a laboratory simulation which seems to deal primarily with subsystems at lower levels of fidelity.

has identified several relevant psychological dimensions of simulation. These include reactions to the scope, extent, or segment of the environment represented in the simulation; the duration of the interaction between man and environment; the degree of mediacy between the person and the raw environment, in terms of both perceptual and effector interactions; the importance and degree of involvement with interpersonal relationships; and the extent of perceived realism and related cognitive states. It is necessary to determine how the tasks observed in the operational system are related to these or other dimensions, and how accurately they must be represented in the simulation for optimum transfer.

Conceptual Framework for Simulation

Figure 1 provides both a review and a perspective for the points we have covered. On the left are seven steps or decisions that must be accomplished to successfully apply simulation techniques and meet specified objectives in terms of transfer and cost. Listed at the top are the four areas where simulation techniques have been applied. These provide a definition of user need or the purpose of the simulation. Most, if not all, of these purposes probably would be included in the simulation of any given system.

A systems analysis will provide the basis for effective application of simulation techniques. The results of this analysis will consist of the performance requirements of the system and the necessary perspectives concerning the relationships between various system aspects. We must have complete and accurate information concerning the system aspects of interest before proceeding with the selection of system elements for simulation.

The next phase in the application of simulation techniques is the analysis of performance requirements and conditions of performance to determine where simulation will be most effective. We must examine these performances in terms of our cost and transfer objectives to determine whether simulation will provide the most cost-effective approach. Other factors that may not be directly related to the costs involved such as the reasons for simulation and the associated advantages should also be considered.

The most important step in the application of simulation is probably the selection of specific system elements for representation. Using those performance requirements where simulation will be cost-effective, we must now specify the critical knowledges and performances that should be included in the simulation. These knowledges and performances are all the psychological dimensions or attributes contained in the performance requirements that should be represented in the simulation for maximum transfer. Our objective is to determine which dimensions or attributes should be represented to achieve our desired levels of transfer at minimum cost.

In constructing the simulated environment, we must determine the levels of physical and psychological fidelity required in the simulation to accurately represent the critical knowledges and performances. The levels of fidelity selected must also be cost-effective in terms of the amount of transfer observed. When there is insufficient information concerning the required levels of physical and psychological fidelity, there appears to be a tendency to resort to high physical fidelity as a precaution. The purpose of high physical fidelity is to provide psychological fidelity for those perceptual and perceptual-motor tasks that are highly dependent on the equipment. In these cases, the added realism in the interface and task demands obtained through high physical fidelity will probably increase the levels of psychological fidelity.

We must ensure in our construction of the simulation, however, that high physical fidelity is an actual requirement related to the psychological dimensions of the performance. If high physical fidelity is included unnecessarily, it becomes very difficult to achieve cost-effective transfer. The compromises made between physical fidelity, psychological fidelity, cost, and transfer require constant and thorough evaluation to ensure that the most cost-effective simulation has been attained.

Conceptual Framework for Simulation

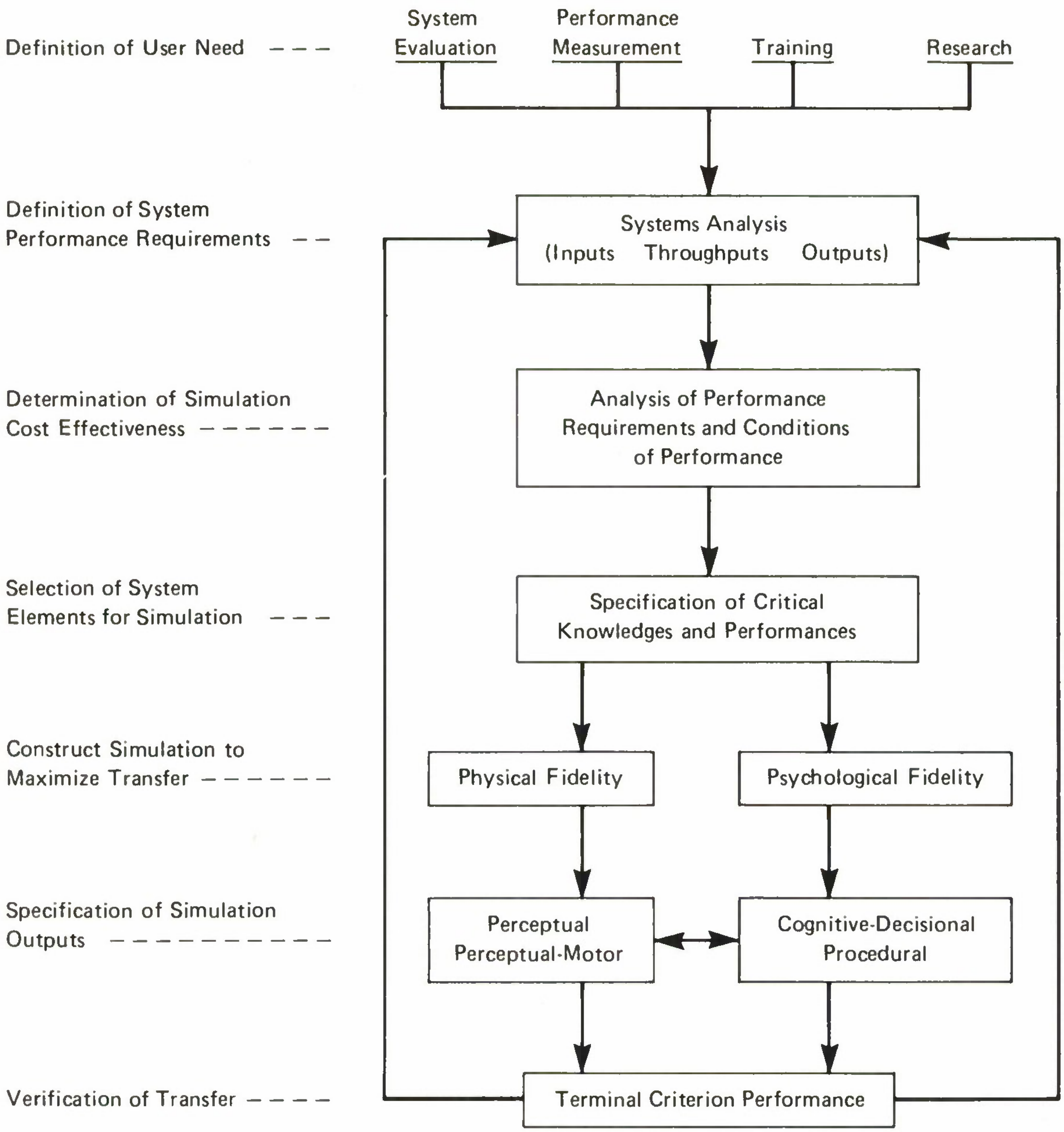

Figure 1

The general form or type of simulation will determine how the psycholgical dimensions will be measured as outputs. In order to obtain accurate information on the degree of transfer, the methods used to measure the outputs must be valid and reliable with respect to the critical knowledges and performances.

In those systems where real-world validation is possible, the extent of transfer will be determined by the terminal criterion performance. In the event that the degree of transfer observed is not acceptable, we must return to a more general level of analysis and question the adequacy of our decision concerning what to simulate at what level of fidelity.

Applications of Miniaturization

We can now turn to some of the practical applications of miniaturization techniques to various types of Army training. In general, these techniques have been effective and have demonstrated the potential of miniaturization as a cost-effective training methodology.

Aircraft recognition is an area where miniaturized training has been successful in providing the required skills (Baldwin, 1970). After receiving classroom training in aircraft recognition, observers were given a field test in a miniature environment using 1/72 scale model aircraft. It was found that the slant range to the aircraft at the time of identification was not significantly different between groups that were field trained and those trained in the miniature environment.

Miniaturization techniques have also been found useful in tactical training for tank platoons (Baker, *et al.*, 1964). It was found that personnel trained with the miniature armor battlefield and the armor combat decision game were superior to untrained subjects, but they still required some field training to achieve a state of combat readiness.

Range estimation training for the purpose of determining the effective range of small arms has also been subjected to miniaturization (McCluskey, 1968, 1971). Observers were trained to determine the range to 1/48 scale model aircraft in a miniature environment and then tested in a full-scale environment to determine the extent of transfer. It was found that the level of performance demonstrated at the end of training in the miniature situation transferred to the full-scale environment for those range determinations that were made when the aircraft was inbound. For the outgoing direction of flight, however, the judgments made in the field were underestimates of the range requested, whereas in the miniature situation these judgments were quite accurate.

The M16 has been recently fitted with a prototype of a laser training device for test and evaluation. It appears that this device has considerable potential for simulating or miniaturizing numerous firing environments. The device was recently tested during some field firing exercises normally conducted in Basic Rifle Marksmanship. Four experimental groups fired six field exercises using either all ball ammunition, one-half laser firing and one-half ball firing, one-half ball and one-half laser, or all laser firing. It was found that there were no significant differences between any of the groups on their Record Fire I and II scores. This indicates that the laser training device may be used in place of live firing for three or six exercises without decreasing end-of-course performance.

In summary, these kinds of simulation and miniaturization techniques appear to have a large potential for use in military training. Recognizing the current economic conditions and staffing levels, simulation may be one of the few cost-effective alternatives available to provide training for many of the systems. If high levels of training effectiveness and readiness are to be maintained, we must seriously consider the use of simulation.

Before these techniques reach maximum levels of effectiveness, however, considerable research is needed to define the conditions of transfer to the real world. After a

Miniature Ranging Apparatus

Figure 2

Laser Training Device

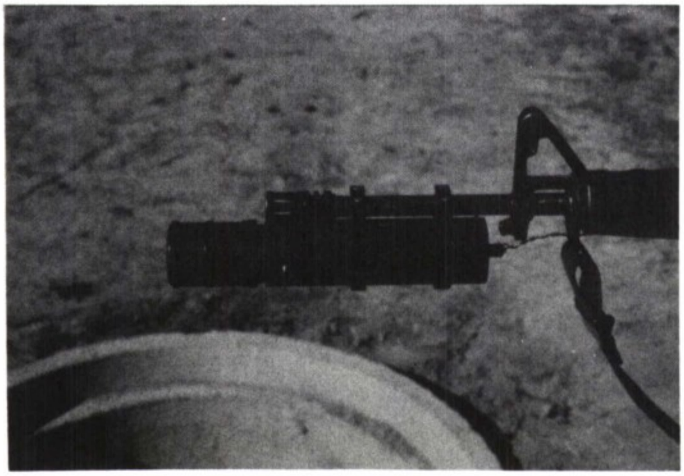

Figure 3

complete systems analysis to define the physical and psychological dimensions and relationships, the following research questions may be addressed:

(1) What task and equipment aspects require high fidelity representation?
(2) What are the most cost-effective levels of fidelity?
(3) What is the most effective combination of simulated and real-world experience?
(4) What are the most effective scale factors for miniaturization?
(5) What relationships exist between psychological fidelity and the scale factors?
(6) What perceptual cues require high fidelity representation?
(7) What relationships exist among the perceptual cues, scale factors, and the task demands?

As we begin to answer these questions, simulation and miniaturization techniques should develop as some of the most cost-effective methodologies for training.

LITERATURE CITED

Baker, Robert A., Cook, John G., Warnick, William L., and Robinson, James P. *Development and Evaluation of Systems for the Conduct of Tactical Training at the Tank Platoon Level*, HumRRO Technical Report 88, April 1964.

Baldwin, Robert D., Frederickson, Edward W., and Hackerson, Edward C. *Aircraft Recognition Performance of Crew Chiefs With and Without Forward Observers*, HumRRO Technical Report 70-12, August 1970.

Bogdanoff, E., Brooks, H.E., Jasinski, F.J., Keys, L.B., Michael, A.L., Molnar, A.R., Proctor, G.L., Reeves, E.Y., and Thorsell, B.A. *Simulation: An Introduction to a New Technology*, Technical Memorandum 499, System Development Corporation, Santa Monica, California, March 1960.

Cox, John A., Wood, Robert O., Jr., Boren, Lynn M., and Thorne, H. Walter. *Functional and Appearance Fidelity of Training Devices for Fixed-Procedures Tasks*, HumRRO Technical Report 65-4, June 1965.

Crawford, Meredith P. *Simulation in Training and Education*, HumRRO Professional Paper 40-67, September 1967, presentation at NATO Symposium on "The Simulation of Human Behavior," Paris, France, July 1967.

Fitzpatrick, Robert. *Toward A Theory of Simulation*, System Development Corporation, Santa Monica, California, November 1962.

Gagne, Robert M. "Training Devices and Simulators: Some Research Issues," *The American Psychologist*, 1954, vol. 9, no. 3, pp. 95-107.

Grimsley, Douglas L. *Acquisition, Retention, and Retraining: Effects of High and Low Fidelity in Training Devices*, HumRRO Technical Report 69-1, February 1969.

Harmon, Harry H. *Simulation: A Survey*, System Development Corporation, Santa Monica, California, July 1961.

Isley, Robert N. *Inflight Performance After Zero, Ten, or Twenty Hours of Synthetic Instrument Flight Training*, HumRRO Professional Paper 23-68, June 1968.

McCluskey, Michael R. *Studies on Reduced-Scale Ranging Training With a Simple Range Finder*, HumRRO Technical Report 71-24, December 1971.

McCluskey, Michael R., Wright, A.D., and Frederickson, E.W. *Studies on Training Ground Observers to Estimate Range to Aerial Targets*, HumRRO Technical Report 68-5, May 1968.

Muckler, F.A., Nygaard, J.E., O'Kelly, L.I., and Williams, A.C., Jr. *Psychological Variables in the Design of Flight Simulators for Training*, WADC Technical Report 56-369, ASTIA Document No. AD 97130, Aero Medical Laboratory, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, January 1959.

Prophet, Wallace W., and Boyd, H. Alton. *Device-Task Fidelity and Transfer of Training: Aircraft Cockpit Procedures Training*, HumRRO Technical Report 70-10, July 1970.

Redgrave, Michael J. *Some Approaches to Simulation, Modeling, and Gaming at SDC*, System Development Corporation, Santa Monica, California, March 1962.

Rogers, Miles S. *The Appropriate Contribution of Simulation Techniques to System Training*, System Development Corporation, Santa Monica, California, 1959.

Smode, Alfred F., Gruber, Alin, and Ely, Jerome H. *Human Factors Technology in the Design of Simulators for Operator Training*, Technical Report NAVTRADEVCEN 1103-1, U.S. Naval Training Device Center, Port Washington, New York, December 1963.

Smode, Alfred F., Gruber, Alin, and Ely, Jerome H. *The Measurement of Advanced Flight Vehicle Crew Proficiency in Synthetic Ground Environments*, Technical Documentary Report No. MRL-TDR-62-2, 6570th Aerospace Medical Research Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, February 1962.

SUPPLEMENTARY BIBLIOGRAPHY

Adams, Jack A. "Part Trainers," in Glen Finch (Ed.), *Educational and Training Media*, Washington, D.C., National Academy of Sciences, National Research Council, August 1959, pp. 129-149.

Barrett, Gerald V., Kobayashi, Minoru, and Fox, Bernard H. "Driving at Requested Speed: Comparison of Projected and Virtual Image Displays," *Human Factors*, 1968, vol. 10, no. 3, pp. 259-262.

Berkun, Mitchell M., Bialek, Hilton M., Kern, Richard P., and Yagi, Kan. *Experimental Studies of Psychological Stress in Man*, HumRRO Research Report 10, December 1962.

Biel, W.C., Harman, H.H., and Sheldon, M.S. *Exercising Teams in Military Systems Through the Use of Simulation*, System Development Corporation, Santa Monica, California, October 1964.

Blaiwes, Arthur S., and Regan, James J. *An Integrated Approach to the Study of Learning, Retention, and Transfer—A Key Issue in Training Device Research and Development*, Technical Report NAVTRADEVCEN IH-178, Naval Training Device Center, Orlando, Florida, August 1970.

Bowen, Hugh M., Hale, Allen, and Kelley, Charles R. *Tracking Training V: Field Study of the Training Effectiveness of the General Vehicular Research Tool*, Technical Report NAVTRADEVCEN 955-1, U.S. Naval Training Device Center, Port Washington, New York, December 1962.

Bushnell, Don D. *System Simulation: A New Technology for Education*, System Development Corporation, Santa Monica, California, April 1962.

Caro, Paul W. *Adaptive Training—An Application to Flight Simulation*, HumRRO Professional Paper 5-70, March 1970.

Caro, Paul W. *Equipment-Device Task Commonality Analysis and Transfer of Training*, HumRRO Technical Report 70-7, June 1970.

Cook, LTC John G. (Ret), and Baker, Robert A. "Armored Cavalry Platoon Training and Evaluation: I. The Armored Cavalry Platoon Combat Readiness Check," *Armor*, January-February 1967, vol. LXXVI, no. 1, pp. 18-23; "II. Act I: Can Reality Be Duplicated?" *Armor*, March-April 1967, vol. LXXVI, no. 2, pp. 38-43.

Crawford, Meredith P. *Dimensions of Simulation*, HumRRO Professional Paper 5-66, October 1966, pp. 788-796; reprinted from *American Psychologist*, vol. 21, no.8, August 1966.

Davis, Robert H., and Behan, Richard A. "Evaluating System Performance in Simulated Environments," in *Psychological Principles in System Development*, Robert M. Gagne (Ed.), Holt, Rinehart and Winston, Inc., New York City, 1962, pp. 477-515.

DePauli, John F., and Parker, Edward L. *The Introduction of the Generalized Sonar Maintenance Trainer into Navy Training for an Evaluation of Its Effectiveness*, Technical Report NAVTRADEVCEN 68-C-0005-1, Naval Training Device Center, Orlando, Florida, April 1969.

Dougherty, Dora J., Houston, Robert C., and Nicklas, Douglass R. *Transfer of Training in Flight Procedures From Selected Ground Training Devices to the Aircraft*, Technical Report NAVTRADEVCEN 71-16-16, Naval Training Device Center, Port Washington, New York, September 1957.

Geisler, Murray A., Ginsberg, Allen S. *Man-Machine Simulation Experience*, The Rand Corporation, Santa Monica, California, August 1965.

Grodsky, Milton A. "The Use of Full Scale Mission Simulation for the Assessment of Complex Operator Performance," *Human Factors*, 1967, vol. 9, pp. 341-348.

Jeantheau, G.G. "The Use of Multi-Man System Trainers," *Ergonomics*, 1969, vol. 12, no. 4, pp. 533-542.

Kelley, Charles R., and Wargo, Michael J. *Adaptive Techniques for Synthetic Flight Training Systems*, Technical Report NAVTRADEVCEN 68-C-0136-1, Naval Training Device Center, Orlando, Florida, October 1968.

Knowles, William B. "Aerospace Simulation and Human Performance Research," *Human Factors*, 1967, vol. 9, no. 2, pp. 149-159.

Lee, Gilbert B. *The Construction of a Model Terrain Simulator at a Scale of 1:108*, (Report of Project MICHIGAN, Report No. 2144-342-T, Copy 169), University of Michigan, Willow Run Laboratories, Ann Arbor, March 1959.

Lumsdaine, Arthur A. "Design of Training Aids and Devices," in *Human Factors Methods for System Design*, John D. Folley, Jr., Ed., AD No. 232 646, 1960.

Lumsdaine, A.A. "Graphic Aids, Models, and Mockups as Tools for Individual and Classroom Instruction," in *Educational and Training Media*, Glen Finch (Ed.) National Academy of Sciences—National Research Council, Washington, D.C., August 1959, pp. 69-113.

Meyer, Donald F., Flexman, Ralph E., Gundy, E.A., Van, Killian, David C., and Lanahan, C.I. *A Study of Simulator Capabilities in an Operational Training Program*, Technical Report AMRL-TR-67-14, Aerospace Medical Research Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, May 1967.

Muckler, F.A., Obermayer, R.W., Hanlon, W.H., and Serio, F.P. *Transfer of Training With Simulated Aircraft Dynamics: III. Variations in Course Complexity and Amplitude*, WADD Technical Report 60-615 (III), Aerospace Medical Research Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, December 1961.

Newton, John M. *Training Effectiveness as a Function of Simulator Complexity*, Technical Report NAVTRADEVCEN 458-1, U.S. Naval Training Device Center, Port Washington, New York, September 1959.

Ozkaptan, Halim, Ohmart, James G., Bergert, James W., King, Barry C., and Clearfield, Warren H. *Investigation of Required Television Parameters for Simulation of the Pilot's Visual World*, Technical Report NAVTRADEVCEN 68-C-0153-1, Naval Training Device Center, Orlando, Florida, December 1969.

Rifkin, Kenneth I., Pieper, William J., and Folley, John D., Jr. *Learner-Centered Instruction (LCI): Volume IV - The Simulated Maintenance Task Environment (SMTE): A Job Specific Simulator*, Technical Report AFHRL-TR-68-14, Air Force Human Resources Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, May 1969.

Roeckelein, Jon E. *Simulation of Organizations: An Annotated Bibliography*, HumRRO Technical Report 67-14, December 1967.

Shure, Gerald H., Rogers, Miles S., and Meeker, Robert J. *Group Decision Making Under Conditions of Realistic Complexity*, System Development Corporation, Santa Monica, California, September 1961.

Vincent, Robert J., Brown, Bill R., Markley, Robert P., and Arnoult, Malcolm D. "Magnitude Estimation of Perceived Distance Over Various Distance Ranges," *Psychonomic Science*, 1968, vol. 13, no. 6, pp. 303-304.